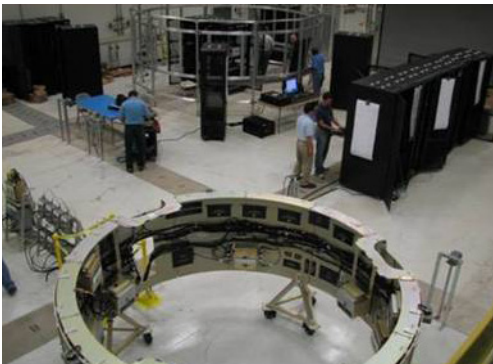# Hardware-in-the-Loop Simulation Lab and Thrust Vector Control Test Lab at Marshall Center's Propulsion Research Laboratory

NASAfacts

The Propulsion Research Laboratory at NASA's Marshall Space Flight Center in Huntsville, Ala., is a central research hub supporting cutting-edge scientific study of advanced software, hardware, propulsion systems and technologies that will enable more ambitious exploration of our solar system. The 108,000-square-foot facility has 26 labs for large- and small-scale experiments.

Among its capabilities, the lab supports programs and projects including the Space Launch System — a new U.S. heavy-lift launch vehicle for NASA's next generation of human space exploration beyond low-Earth orbit. The Hardware-in-the-Loop Simulation Lab and the Thrust Vector Control Test Lab provide integrated test environments for the Space Launch System's guidance, navigation and control software and hardware and avionics hardware.
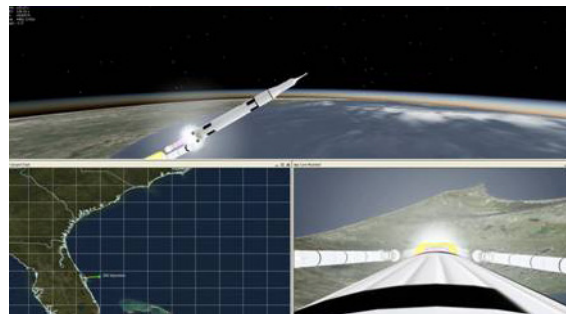


**Engineers in the Hardware-in-the-Loop Simulation Lab prepare avionics and software for testing. (NASA/MSFC)**

## Hardware-in-the-Loop Simulation Lab Capability

The Hardware-in-the-Loop (HWIL) Simulation Laboratory supports end-to-end integrated avionics and software integration, check-out, verification and validation. This capability includes A Real-Time Environment for Modeling, Integration and Simulation (ARTEMIS) – a suite of models,

simulations and hardware interfaces used for stimulating avionics hardware and software. The Managed Automation Environment for Simulation, Test, and Real-Time Operations (MAESTRO) is an automation environment tool that configures and controls the test operations, sets up test configurations, executes and monitors tests scenarios and provides data archiving for retrieval and analyses.



**Using the ARTEMIS and MAESTRO tools, engineers in the Hardware-in-the Loop Simulation Lab can create real-time launch vehicle simulations of the Space Launch System — NASA's new heavy-lift launch vehicle designed to take astronauts, cargo and science experiments to destinations in deep space. (NASA/MSFC)**

The lab design resulted from benchmarking state-of-the-art HWIL facilities, previous Marshall HWIL facilities, as well as teaming with industry experts in Real-Time Modeling and Simulation development of HWIL facilities.

Key design features of the lab include:
- Real-time launch vehicle simulation of the Space Launch System

- Trajectory simulation that can track real-time multiple-vehicle configurations and stages

- Rapid vehicle re-configurability including vehicle geometry, aerodynamics, Guidance, Navigation & Control (GN&C) algorithms and data, GN&C sensor location and types/locations of flight control end effectors

- Modular lab design to provide a variety of simulation designs to meet the unique needs of each program and project
- Rapid integration of MatLab/Simulink tools

The HWIL Simulation Lab has extensive capabilities to support all program/project phases. Early hardware/software integration and testing reduces risks and saves overall cost and schedule throughout a program/project life cycle. By performing early hardware/software integration, potential architecture and interface-related problems can be identified, and thus reduce associated risk as early in the design cycle as possible when problems are the least expensive to resolve while also improving the design and requirements.

## Thrust Vector Control Test Lab Capability

The Thrust Vector Control Test Lab supports the development, certification and qualification testing of control mechanisms, primarily Thrust Vector Control (TVC) actuators and systems — electro-mechanical or electro-hydraulic mechanisms that vector the vehicle's propulsion system, guiding the vehicle during flight. The lab provides dynamic actuator testing with inertial simulators that simulate the nozzle forces acting on the TVC actuators to define the systems' dynamic characteristics. Static load benches, housed in the lab, apply a constant force to verify the static operating charac-



**NASA Administrator Charles Bolden, second from left in foreground, visited the Thrust Vector Control Test Lab at the Marshall Space Flight Center November 2011. He discussed the lab's capabilities with Marshall team members, in foreground from left, Kendall Junen, Space Launch System booster control systems manager and, center, Lisa Bates, TVC systems integration and components branch chief. (NASA/MSFC)**

teristics of the actuator. The static load benches can apply loads up to 100,000 pounds. The lab has supported testing of TVC systems for a wide range of propulsion systems, from MC-1 class engines providing 60,000 pounds of thrust, to solid rocket boosters providing 3 million pounds of thrust.

Battery modules and a 300-volt variable electric power supply provide power for electric actuators, while a variable-flow hydraulic power supply provides up to 3,500 psi hydraulic pressure and up to 500 gallons per minute flow to hydraulic components. The lab also provides control and data acquisition systems to send commands to the actuators and evaluate how the actuators perform.

The Automatic Dynamic Acceptance Procedure Test Stand (ADAPTS), a hydraulic pump test stand that performs acceptance testing for flight pumps, also is housed in the lab. The lab has supported the Space Shuttle Program's solid rocket boosters and space shuttle main engines, Ares I and Ares I-X, Space Operations Mission Directorate TVC capability demonstration and enhancements, and the Space Launch System.

The Thrust Vector Control Test Lab enables significant risk reduction, cost and schedule efficiency throughout a program/project life cycle by performing early integration and testing of engine hardware.
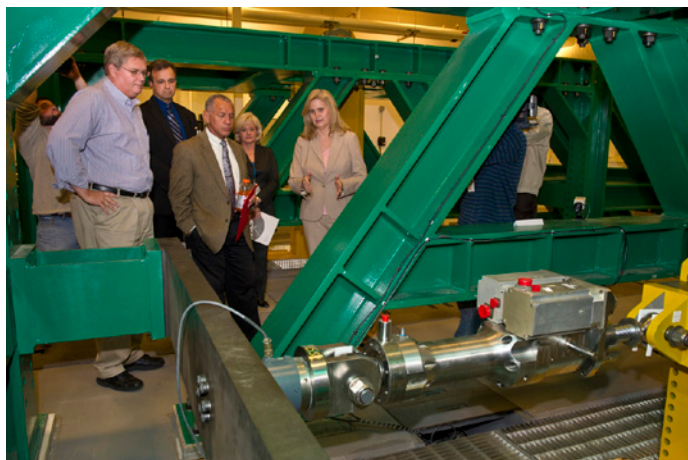
The Hardware-in-the-Loop Simulation Lab and the Thrust Vector Control Test Lab also can be integrated together to develop and test multiple components of avionics and software to provide an even more comprehensive early integration to support programs and projects.

For more information on the Propulsion Research Laboratory, visit

**http://www.nasa.gov/centers/marshall/pdf/143036main_prl.pdf**

For more information on the Space Launch System, visit

**http://www.nasa.gov/exploration/systems/sls/**